NUMERICAL STUDIES OF ROUGH SURFACE SCATTERING MODELS

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Award No.: N00014-97-1-0079
Shallow-Water Acoustics

LONG-TERM GOALS

To understand the effects of the rough air-sea interface and ocean bottom on acoustic propagation.

OBJECTIVES

To develop and study existing approximate theoretical models for rough surface scattering. In particular, to ascertain their applicability and potential usefulness in practical models of acoustic propagation and scattering.

APPROACH

Our primary focus has been on the small slope approximation (SSA) which we have studied for a number of different problems, including acoustic scattering from the air-sea interface and from the ocean bottom. Recently, we have also begun an investigation of the nonlocal SSA (NLSSA) which is an extension of the SSA. Finally, we have been developing a Monte Carlo Finite-Difference Time-Domain (FDTD) technique for scattering from both the rough ocean surface and bottom. This ``exact" technique can be used to benchmark approximate theoretical models for rough surface scattering and to study the effects of surface roughness on a propagating signal.

WORK COMPLETED

The second part of a study of the SSA was published in JASA in May 1997 [1]. It presented a detailed numerical study of the SSA for 2-D, Dirichlet surfaces with Gaussian statistics and a Gaussian roughness spectrum. Our initial study of the NLSSA has included derivation of the lowest-order scattering cross section and calculation of several examples for 2-D, Dirichlet surfaces with Gaussian statistics and a Gaussian roughness spectrum [2],[3]. Development of the FDTD method, done in collaboration with John Schneider, has resulted in an improved absorbing boundary condition for elastic wave problems [4] and Monte Carlo FDTD algorithms for scattering from pressure-release surfaces [5],[6] and from fluid-fluid interfaces [7].

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**
4. TITLE AND SUBTITLE **Numerical Studies of Rough Surface Scattering Models**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Washington State University,School of Electrical Engineering & Computer Science,Pullman,WA,99164**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

Our study of the SSA indicates that it may be a good replacement for small perturbation theory and the Kirchhoff approximation (KA) in many practical models. While the higher order SSA is too computationally costly, the lowest-order involves the same integral as does the KA; yet it is much more accurate at low forward grazing angles than the KA and no worse than lowest-order perturbation theory in the backscatter region, which does fairly well for power-law type spectra.

It is still too soon to draw conclusions about the NLSSA, but preliminary results are promising. Finally, the Monte Carlo FDTD algorithm results compare well with integral equation results found by Eric Thorsos. Thus, the technique can be extended to problems of greater complexity, beyond the limits of integral equation techniques, with some confidence in the results.

IMPACT/APPLICATIONS

The development of approximate models that accurately predict wave scattering from rough surfaces is important in a number of Navy applications. For example, rough surface scattering models are needed in the simulations used by torpedo guidance and control personnel to test torpedoes. Another application for which rough surface scattering is critical is the detection of underwater mines, especially those buried in soft sediments. Other applications include ship wake detection, communications, and anti-submarine warfare.

TRANSITIONS

Partly as a result of our work, Voronovich was motivated to develop the NLSSA, which introduces nonlocal effects into the same ansatz used to develop the SSA. Also, Darrell Jackson is trying to incorporate the SSA into his high frequency models for penetrable ocean bottoms. Finally, our acoustic animations of wave propagation in a shallow-water waveguide are available via the Web, and videos of these and other animations have been provided to ONR.

RELATED PROJECTS

This research is related to projects in propagation in a shallow-water waveguide such as the work of David Berman and the work of John Schneider, in high-frequency bottom scattering modeling such as the work of Darrell Jackson, in long range propagation, and in rough surface scattering such as the work of Eric Thorsos.

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